TT 50: Quantum-Critical Phenomena I

Time: Wednesday 9:30–13:00 Location: H 3005

TT 50.1 Wed 9:30 H 3005

Uniaxial stress tuning of geometrical frustration in a Kondo lattice — R. Küchler[1,2], C. Stingl[2], Y. Tokiwa[2], M.S. Kim[3], T. Takabatake[3], and •P. Gegenwart[2] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [3]Department of Quantum Matter, ADSM, Hiroshima University, Higashi-Hiroshima, 739-8530, Japan

Hexagonal CeRhSn with paramagnetic $4f$ moments on a distorted Kagome lattice displays zero-field quantum critical behavior related to geometrical frustration [1]. We report high-resolution thermal expansion and magnetostriction measurements under multiextreme conditions such as uniaxial stress up to 200 MPa, temperatures down to 0.1 K and magnetic fields up to 10 T. Under uniaxial stress along the a-direction, quantum criticality disappears and a complex magnetic phase diagram arises with a sequence of phases below 1.2 K and fields between 0 and 3 T ($\parallel a$). Since the Kondo coupling increases with stress, which alone would stabilize paramagnetic behavior in CeRhSn, the observed order arises from the release of geometrical frustration by in-plane stress.

[1] Y. Tokiwa, C. Stingl, M.-S. Kim, T. Takabatake, and P. Gegenwart, Sci. Adv. 1, e1500001(2015).

TT 50.2 Wed 9:45 H 3005

Close proximity of FeSe to a magnetic quantum critical point as revealed by high-resolution μSR measurements — •Vadim Grinenko[1,2], Rajib Sarkar[1], Philipp Materne[1], Sirko Kamusella[1], Aichi Yamashita[3], Yoshihiko Takano[3], Yue Sun[4], Tsuyoshi Tamegai[4], Dmitriy Efremov[2], Stefan-Ludwig Drechsler[2], Jean-Christophe Orain[5], Tatsuo Goko[5], Robert Scheuermann[5], Hubertus Luetkens[5], and Hans-Henning Klauss[1] — [1]Institute for Solid State and Material Physics, TU Dresden, 01069 Dresden, Germany — [2]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [3]National Institute for Materials Science (NIMS), Tsukuba, Ibaraki, 305-0047 JAPAN, Japan — [4]Department of Applied Physics, The University of Tokyo, Hongo, Tokyo 113-8656, Japan — [5]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute (PSI), CH-5232 Villigen, Switzerland

We investigated FeSe single crystals using high-field (up to 9.5 T) muon spin rotation (μSR) measurements. We observed that the muon spin depolarization rate follows a critical behavior $\Lambda^2 \propto T^{-3/4}$ in the temperature range $T_s \gtrsim T \gtrsim 10$ K. The scaling between Λ^2 and the NMR $1/T_1T$ suggests that $\Lambda \propto 1/T_2$ spin-spin relaxation rate. The observed non-Fermi liquid behavior with a cutoff at $T^* \sim 10$ K indicates that FeSe is close to a magnetic quantum critical point. The μSR Knight shift and the bulk susceptibility linearly scale at high temperatures but deviate from this behavior below T^* where the Knight shift exhibits a kink. Our analysis shows a reduction of the density of states crossing the region near T^* maybe related to a Lifshitz transition.

TT 50.3 Wed 10:00 H 3005

Detailed study of the transverse susceptibility of the model magnet $LiHoF_4$ — •Felix Rucker[1], Christopher Duvinage[1], Steffen Säubert[1,2], Robert Georgii[2], Andreas Wendl[1], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik-Department, Lehrstuhl für Topologie korrelierter Systeme — [2]Heinz Maier-Leibnitz Zentrum, TUM, Garching, Germany

The low temperature properties of $LiHoF_4$, representing a model system for a magnetic field tuned quantum phase transition, have been investigated for over two decades. Despite recent experimental and theoretical efforts, details of the experimentally inferred magnetic phase diagram remain inconsistent with theoretical predictions. In our study, we revisit magnetic transverse susceptibility measurements at low temperatures. We find evidence for the influence of the hyperfine coupling on the magnetic transverse susceptibility, yielding insights to the dynamic properties of the quantum phase transition.

TT 50.4 Wed 10:15 H 3005

Antiferromagnetic correlations in ferromagnetic $YbNi_4P_2$ — •Zita Huesges[1], Stefan Lucas[2], Kristin Kliemt[3], Cornelius Krellner[3], Astrid Schneidewind[4], and Oliver Stockert[2] — [1]Helmholtz-Zentrum Berlin GmbH — [2]MPI Chemische Physik fester Stoffe, Dresden — [3]Goethe-Universität Frankfurt am Main — [4]Forschungszentrum Jülich GmbH, Outstation MLZ

$YbNi_4P_2$ is one of the very few heavy-fermion compounds that shows ferromagnetic order at very low temperature. The Curie temperature, only 150 mK in the pure compound, can be suppressed to zero by As substitution on the P site. Upon substitution, the transition stays second order, thus leading to a ferromagnetic quantum critical point. While the c-axis is the magnetic easy axis in the paramagnetic phase, magnetic order occurs with the moments aligned in the ab-plane.

To gain microscopic insights into this unusual behaviour, we have performed inelastic neutron scattering (INS) experiments at the triple-axis spectrometers PANDA (MLZ) and FLEXX (HZB). Large single crystals have recently become available due to progress in sample preparation. Remarkably, we observe an INS signal at low-Q antiferromagnetic positions. The signal appears to be quasi-elastic, it is present at much higher temperatures than T_C, and it shows no signature of a moment-reorientation. This indicates that only a fraction of the magnetic moment participates in the low-temperature ferromagnetic order, while antiferromagnetic correlations are present in a broader temperature range.

TT 50.5 Wed 10:30 H 3005

Fermi surface studies of $YbNi_4P_2$ — •Sven Friedemann[1], Alix McCollam[2], Gertrud Zwicknagl[3], Kristin Kliemt[4], and Cornelius Krellner[4] — [1]HH Wills Laboratory, University of Bristol, UK — [2]High Field Magnet Laboratory, University of Radboud, Nijmegen, NL — [3]Institut für Mathematische Physik, TU Braunschweig, Braunschweig, Germany — [4]Physikalisches Institut, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

$YbNi_4P_2$ is a rare example of a heavy-fermion compound with ferromagnetic (FM) order. Moreover, FM order can be suppressed and a FM quantum critical point (QCP) can be accessed if phosphorous is partially substituted by arsenic [1]. The presence of a FM QCP makes $YbNi_4P_2$ unique as FM QCPs are avoided in most systems through a change of the transition to 1st order or through an intervening antiferromagnetic phase. The preservation of the FM QCP is theoretically suggested to be due to an effective one-dimensional electronic structure. Here, we present quantum oscillation measurements performed at high magnetic fields and low temperatures. We compare the angular dependency of the observed frequencies with predictions from band structure calculations treating the f electrons as core electrons and with predictions from fully renormalised band structure calculations.

[1] A. Steppke et al., Science, **339**, 933 (2013).

TT 50.6 Wed 10:45 H 3005

Characterization of substituted $YbNi_4P_2$ single crystals — •Kristin Kliemt[1], Paul Denck[1], Philipp Ross[1], Jacintha Banda[2], Sandra Hamann[2], Alexander Steppke[2], Sven Friedemann[3], Manuel Brando[2], and Cornelius Krellner[1] — [1]Goethe-University Frankfurt, Institute of Physics, 60438 Frankfurt, Germany — [2]MPI CPfS, 01187 Dresden, Germany — [3]University of Bristol, Bristol, United Kingdom

The tetragonal compound $YbNi_4P_2$ has a low Curie temperature, $T_C = 0.17$ K, which can be further suppressed by substituting P by As and the rare case of a ferromagnetic quantum critical point occurs in the substitution series $YbNi_4(P_{1-x}As_x)_2$ at $x \approx 0.1$ [1,2]. Here, we present the characterization of $YbNi_4(P_{1-x}As_x)_2$ single crystals [3,4] with As concentrations $0 \leq x \leq 1$ by electrical transport, heat capacity and magnetization measurements. We also discuss the effect on the magnetic ordering temperature of a substitution at the Yb site by hafnium and scandium.

[1] C. Krellner et al., New J. Phys. **13**, 103014 (2011)
[2] A. Steppke et al., Science **339**, 933 (2013)
[3] K. Kliemt, C. Krellner, J. Cryst. Growth **449**, 129 (2016)
[4] K. Kliemt, C. Krellner, J. Phys.: Conf. Series **807**, 032005 (2017)

TT 50.7 Wed 11:00 H 3005

High field NMR near the field induced quantum phase transition in $CeRhIn_5$ — •Guilherme G. Lesseux[1,2], Taisuke Hattori[3], Hironori Sakai[3], Yo Tokunaga[3], Shinsaku Kambe[3], Philip Kuhns[4], Arneil Reyes[4], Pascoal J. G. Pagliuso[1], and

Ricardo R. Urbano[1] — [1]"Gleb Wataghin" Institute of Physics - University of Campinas, Campinas, Brazil — [2]1. Physikalisches Institut - Universität Stuttgart, Stuttgart, Germany — [3]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki, Japan — [4]National High Magnetic Field Laboratoy - Florida State University, Tallahassee, USA

We report on the first low temperature and high field ^{115}In NMR measurements on $CeRhIn_5$ through its magnetic field induced transition at $B^* \sim 30$ T (0.5 K) near the quantum critical point at $B_{c0} \sim 50$ T. With the magnetic field applied along c-axis and within the limit of the signal-to-noise ratio, no remarkable change of the spectral shape of the planar In(1) signal was observed in the range 2 T $< B||c <$ 39 T, indicating no significant change of the magnetic structure. Moreover, the formal shift for the In(1) transitions was found to be virtually constant from the lowest measured field (2 T) up to 29 T although its value revealed a noticeable change through 30 T. Our results are the first microscopic evidence of the high field induced Fermi surface reconstruction in $CeRhIn_5$ suggested in previous reports based on quantum oscillations.

15 min. break.

Invited Talk TT 50.8 Wed 11:30 H 3005

Critical Phonon Softening Near a Structural Instability at $T = 0$ — •Oliver Stockert — Max-Planck-Institut CPfS, Dresden

While lots of studies have focused on magnetic quantum critical points, remarkably little is known about structural instabilities occurring at $T = 0$. Technological improvements made it recently possible to observe low-energy phonons and phonon softening by high-resolution inelastic x-ray scattering (IXS) with energy resolution of about 1 meV, i.e. quite similar to inelastic neutron scattering (INS). We have studied in detail the lattice dynamics in the quantum critical charge density wave system $Lu(Pt_{1-x}Pd_x)_2In$ [1] using both INS and high-resolution IXS. Superconductivity in this system displays a pronounced maximum of the transition temperature in the vicinity of the structural quantum criticality at $x_c \approx 0.6$ [1]. We were able to trace the softening of the critical phonon modes down to energies of < 0.5 meV using INS and even IXS. Importantly, the results of both methods match, showing the capabilities of IXS. The precise information on the temperature evolution of the critical modes provided by these experiments is essential to get an understanding of the unusual properties observed in such quantum critical systems, e.g. for the emergence of unconventional superconductivity.

[1] T. Gruner et al., Nature Phys. **13**, 967 (2017).

*In collaboration with T. Gruner, S. Lucas, Z. Huesges, K. Kaneko, S. Tsutsui, K. Schmalzl, M. Koza, A. Hoser, M. Reehuis, C. Geibel.

TT 50.9 Wed 12:00 H 3005

Pressure dependent entropy of the partially frustrated heavy-fermion system $CePd_{1-x}Ni_xAl$ — •Sebastian Kuntz[1], Kai Grube[1], Chien-Lung Huang[2], Veronika Fritsch[3], and Hilbert von Löhneysen[1,4] — [1]Institut für Festkörperphysik, Karlsruher Institut für Technologie, 76021 Karlsruhe, Germany — [2]Department of Physics and Astronomy, Rice University, Houston, Texas 77005, United States — [3]Experimentalphysik VI, Elektronische Korrelationen und Magnetismus, Universität Augsburg, 86159 Augsburg, Germany — [4]Physikalisches Institut, Karlsruher Institut für Technologie, 76049 Karlsruhe, Germany

In CePdAl one third of the Ce moments are geometrically frustrated and do not participate in the antiferromagnetic long-range order below $T_N = 2.7$ K. By replacing Pd with isoelectronic, but smaller Ni atoms, the magnetic order can be suppressed at a Ni concentration of $x = 0.14$ [1]. We measured the thermal expansion of $x = 0$, 0.05 and 0.14 single crystals in magnetic fields up to $B = 14$ T to obtain the uniaxial pressure dependences of the entropy $S(T)$ and the ordering temperature T_N. The results will be compared with magnetization measurements of CePdAl under hydrostatic pressure. The impact of external and chemical pressure on the geometric frustration and the Kondo effect will be discussed.

[1] A. Sakai *et al.*, Phys. Rev. B 94, 22045(R) (2016).

TT 50.10 Wed 12:15 H 3005

Investigation of a field induced magnetic transition in the low-dimensional magnet $BiCoPO_5$ — •Margarita Iakovleva[1,2], Evgeniia Vavilova[2], Hans-Joachim Grafe[1], Alexey Alfonsov[1], Bernd Büchner[1], Yurii Skourski[3], Ramesh Nath[4], and Vladislav Kataev[1] — [1]IFW Dresden, Dresden, 01069, Germany — [2]KPhTI, Kazan, 420029, Russia — [3]HZDR, Dresden, 01328, Germany — [4]IISER, Kerala, 695016, India

The frustrated dimeric chain compound $BiCoPO_5$ orders antiferromagnetically at $T_N = 11$ K. Application of an external magnetic field reduces the transition temperature down to T = 0 K at field of $H_C \approx$ 15.3 T [1], which according to theory could be a signature of field driven quantum phase transition [2]. Here we present an investigation of the title compound by means of magnetometry, high-field/frequency electron spin resonance (HF-ESR) and nuclear magnetic resonance (NMR) techniques. The high-field magnetization measurements show no saturation of the magnetic moment up to the highest magnetic field of 60 T. Low-temperature HF-ESR measurements reveal several field-dependent resonance modes. The ^{31}P NMR relaxation rates measured at 9 T exhibit a peak at T = 8 K corresponding to the AFM order. Remarkably, at a magnetic field of 15 T the T-dependence of the relaxation rates shows a contrasting gapped behavior that could indicate the emergence of a new quantum disordered phase of $BiCoPO_5$ with gapped spin excitations above H_C.

[1] E. Mathews, et. al., Solid State Commu. 154, 56 (2013)
[2] Rong-Gen Cai, et. al., Phys. Rev. D 92, 086001 (2015)

TT 50.11 Wed 12:30 H 3005

High-pressure fermiology of the metallised Mott insulator NiS_2 — •Jordan Baglo[1], Konstantin Semeniuk[1], Hui Chang[1], Xiaoye Chen[1], Pascal Reiss[1], HongEn Tan[1], Patricia Alireza[1], Audrey Grockowiak[2], William Coniglio[2], Stanley Tozer[2], Alix McCollam[3], Inge Leermakers[3], Sven Friedemann[4], Monika Gamza[5], and Malte Grosche[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]NHMFL, Tallahassee, Florida, USA — [3]HFML, Nijmegen, The Netherlands — [4]HH Wills Laboratory, University of Bristol, UK — [5]Jeremiah Horrocks Institute, University of Central Lancashire, UK

The Mott metal-to-insulator transition continues to be an active topic of investigation; various mechanisms have been proposed, but the precise nature of the transition remains an open question. In many such systems under study, filling (via chemical doping) is used as a tuning parameter, but the resultant disorder hinders the use of sensitive quantum oscillation techniques to study Fermi surface properties. In the prototypical Mott insulator NiS_2, one can instead use pressure to cleanly tune the ratio U/t of onsite Coulomb repulsion to kinetic energy. We will present our most recent quantum oscillation measurements of NiS_2 under hydrostatic pressures from near the Mott transition at ∼30 kbar up to 115 kbar. We find that the Fermi surface remains nearly unchanged on approaching Mott localisation, whereas the effective mass is strongly renormalised – in qualitative agreement with the Brinkman-Rice picture.

TT 50.12 Wed 12:45 H 3005

Quantum criticality in the spin-1/2 Heisenberg chain system CuPzN — Oliver Breunig[1], Markus Garst[2,3], Andreas Klümper[4], Jens Rohrkamp[1], Mark M. Turnbull[5], and •Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Germany — [3]Institut für Theoretische Physik, Universität Dresden, Germany — [4]Fachbereich C Physik, Bergische Universität Wuppertal, Germany — [5]Carlson School of Chemistry, Clark University, Worcester, USA

The magnetic insulator copper pyrazine dinitrate (CuPzN) is one of the best experimental realizations of the Heisenberg spin-1/2 chain model. Its weak antiferromagnetic coupling J of about 10 K provides a unique opportunity for a quantitative comparison between theory and experiment. Here, we study thermodynamic properties with a particular focus on the magnetic-field induced quantum phase transition at 14 T [1]. Thermal expansion, magnetostriction, specific heat, magnetization and magnetocaloric measurements almost perfectly agree with predictions from exact Bethe-Ansatz results. On approaching the critical field, thermodynamics obeys the quantum critical scaling behavior expected from effective field theory. In particular, the magnetic-field and pressure dependent Grüneisen parameters diverge in a characteristic manner. Our study instructively illustrates fundamental principles of quantum critical thermodynamics and also reveals the influence of corrections to scaling.

Funded by the DFG via FOR 960, FOR2316, CRC1143, and CRC1238.

[1] O. Breunig et al., arxiv1709.00274 (Sci. Adv., to appear).